NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

296 594

3-80-62-17

THERMAL PROPERTIES OF WOOD: AN ANNOTATED BIBLIOGRAPHY

SPECIAL BIBLIOGRAPHY
SB-62-28

SEPTEMBER 1962

3-80-62-17

THERMAL PROPERTIES OF WOOD: AN ANNOTATED BIBLIOGRAPHY

Compiled by
JACK B. GOLDMANN

SPECIAL BIBLIOGRAPHY
SB-62-28

SEPTEMBER 1962

Lockheed

MISSILES & SPACE COMPANY

A GROUP DIVISION OF LOCKHEED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

ABSTRACT

The high temperature possibilities of wood through treatment of various types and its applications are the basis of this annotated bibliography. High temperature is defined as anything up to 1500° F, including char. Laminated wood and plywood were investigated, too.

Search covers period of 1927-1962.

Search completed June 1962.

Availability notices and procurement instructions following the citations are direct quotations of such instructions appearing in the source material announcing that report. The compiler is well aware that many of these agencies' names, addresses and office codes will have changed; however, no attempt has been made to update each of these notices individually.

In citing classified reports, (SECRET TITLE) or (CONFIDENTIAL TITLE) as appropriate, has been used when that classification of the title was indicated on the report. (UNVERIFIED TITLE) has been used when the report was not available to the compiler and it was impossible to verify the report's title and the title's security level.

Classification of classified reports is indicated by abbreviation in upper right top line of bibliographic entry. The classification of the report is given in full, e.g., SECRET REPORT, at the conclusion of the bibliographic data for that report entry.

This selective bibliography has been prepared in response to a specific request and is confined to the limits of that request. No claim is made that this is an exhaustive or critical compilation. The inclusion of any reference to material is not to be construed as an endorsement of the information contained in that material.

TABLE OF CONTENTS

1. Atherton, G. A. and Grantham, J.

HEATING DOUGLAS-FIR VENEER BLOCKS--
DOES IT PAY? Oregon. Forest Products
Research Center, Corvallis. Bulletin
no. 9, June 59, 64p.

In experiments on heated and unheated blocks from two grades of veneer log, the % of A-grade veneer from high-grade logs increased from 48 when unheated to 60 when heated, chiefly as a result of reduced splitting. Cost of heating is estimated at $0.82/1000 bd. ft., giving a net value gain of $4.35.

2. Banfield, W. O. and Peck, W. S.

Effect of chemicals on the ignition temperature
of wood. CANADIAN CHEMISTRY AND METAL-
LURGY v. 6, n. 8, p. 172-176, Aug 1922.

Results of experiments carried out at University of British Columbia to find practical fire-retarding chemical.

3. Bobrov, P. A.

Thermal decomposition of wood with superheated
steam. LESOKHIMIIA PROMYSHLENNOST' v. 4,
n. 3, p. 9-15, 1935. (In Russian)

In distillation of sawdust and wood chips up to 2 x 2 x 4 cm. with superheated steam the yield of acids is raised by 100%, while gases and tar are not produced. With wood in large pieces the yield of acids decreases and there are formed decomposition products, tar and gases. A critical discussion of papers by various authors is presented and a literature index comprising 17 references is attached.

4. Bobrov, P. A.

The thermal decomposition of wood with superheated steam. NARKOMLESA SSR. TSENTRAL. NAUCHNYE ISSLEDOVATELENIE LESOKHIMII INSTITUTA. TRUDY v. 5, p. 3-41, 1934. (In Russian)

Spruce, birch, cedar and other cellular materials in forms of sawdust, chips, and logs were destructively distilled with superheated steam, and the ether-extracted distillate and the nonvolatile residue examined. The distillation was made in a 20-1. vertical, water-jacketed copper retort provided with a top and bottom outlet. The tabulated results show that the decomposition under various conditions of distillation depends chiefly on the nature of wood used. The leafy trees give a greater yield of acids. With an increased amount of steam used the yields of useful products become greater. Under normal conditions of decomposition with steam, no gases or resins are formed. The chief products are H_2O-soluble substances found in the distillate, and some nonvolatile residue obtained in vacuum distillation of the distillate. The percentage of aldehydes is independent of the nature of wood and varies with changes in the procedure of the decomposition. The form of wood and its degree of mechanical disintegration have no effect on the yields of decomposition products. The yields of all products are increased with greater duration of the exothermic reaction at 270°. The method as compared with the destructive distillation without the use of steam gives a greater yield of useful decomposition products, viz., 100% increase in the yield of acids and an equal yield of MeOH. A yield of 40-53% of C was obtained at 310-364°.

5. Bowes, P. C.

ESTIMATES OF THE RATE OF HEAT EVOLUTION AND OF THE ACTIVATION ENERGY FOR A STAGE IN THE IGNITION OF SOME WOODS AND FIBERBOARDS. Gt. Brit. Joint Fire Research Organization. Department of Scientific and Industrial research and Fire Offices' Commission. Fire research note no. 266, 1956, n. p.

6. Brown, C. R.
THE DETERMINATION OF THE IGNITION TEMPERATURES OF SOLID MATERIALS. Catholic University of America, Washington, D. C. 1934. n. p.

Method devised which would be suitable for such material as wood, paper, vegetable fibers, etc; study of effect of size of specimen, rate of air flow, and rate of temperature rise.

7. Brown, C. R.
Determination of the ignition temperature of solid materials. FUEL v. 14, p. 14-18, 56-59, 80-85, 112-116, 149-152, 173-179. 1935.

Method devised which would be suitable for such material as wood, paper, vegetable fibers, etc; study of effect of size of specimen, rate of air flow, and rate of temperature rise.

8. Browne, F. L.
THEORIES OF THE COMBUSTION OF WOOD AND ITS CONTROL: A SURVEY OF THE LITERATURE. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 2136, Dec 58, 71p.

Substantial progress has been made in reaching an understanding of the fundamental mechanisms of the pyrolysis and combustion of wood and of their alteration by added chemicals. No single theory completely describes the manner in which resistance to fire is imparted to wood. In particular, the mechanism of protection against flaming combustion differs essentially from that against glowing combustion.

For resistance to both flame and glow the older physical theories no doubt remain applicable to a certain extent, at least in some cases, but the new chemical theories seem to be of greater and more general significance. The chemical theories especially offer promise of achieving good resistance to fire with smaller expenditures of chemicals than have generally been found necessary in the past. All of the theories, however, still remain too highly speculative because there has been insufficient experimental work to establish properly the extent of their validity and the quantitative details of their applicability. But enough has been learned to afford a good foundation for a thoroughly scientific approach to the problem of imparting better fire resistance to wood. Since empirical efforts for more than a century have added so little to our stock of practicable fire retardants for wood, it is high time that the objective be sought from the point of view of fundamental principles.

9. Browne, F. L. and Tang, W. K.

Thermogravimetric and differential thermal analysis of wood and of wood treated with organic salts during pyrolysis; A Progress Report In AMERICAN CHEMICAL SOCIETY. ABSTRACTS OF PAPERS, 140TH MEETING 3-8 SEP 1961, p. 6K-21.

Thermogravimetric and differential thermal analyses indicated that, in a nitrogen atmosphere, wood, lignin, and cellulose begin to pyrolyze actively during an exothermoic trend in the decomposition process, the lignin near 220°C. and the cellulose near 275°C. Once started, cellulose is volatilized nearly completely and mostly endothermically before 400°C. is reached; whereas lignin volatizes much more slowly, entirely exothermically, and loses only half its weight even at 800°C. Some salts that are good flame retardants lower the threshold temperature for active pyrolysis of wood, increase the volatilization below 250°C., exert an endothermic effect at the temperatures of greatest volatilization, and minimize the amount of wood volatilized when pyrolysis is complete. Other good flame retardants fail to alter the pyrolysis threshold or volatilization below 250°C. and have an exothermic effect at temperatures of greatest volatilization, but they share with the first group the property of minimizing volatilization when pyrolysis is complete.

10. Bruce, H. D. and Downs, L. E.

SURFACE FLAMMABILITY OF VARIOUS WOOD-

BASE BUILDING MATERIALS. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 2140, 1959, n.p.

11. Byvshikh, M. D.

Effect of moisture content and temperature of wood on its elastic and plastic properties. DEREVOOBRABATYVAIUSHCHAIA PROMY-SHLENNOST' v. 8, n. 2, p. 13-15, 1959. (English trans. by D. Pronin. U. S. Forest Products Laboratory, Madison, Wisc. Rept. No. TR-400, 1959, 7p.)

12. Comben, A. J.

The effect of high temperature kiln drying on the strength properties of timber. WOOD (London) v. 20, n. 8, p. 311-313, 1955.

The strength in impact bending, static bending and compression, of Triplochiton, scheroxylon, Mitragyna stipulosa, and Pinus sylvestris, was virtually unaffected by rapid superheated steam drying at 110°C. as compared with that of the same timber bred by normal FPRL schedules. In mahogany (Khaya ivorensis) treated severely, there was a reduction in toughness and impact strength and an increase in brittleness. Kiln schedules are tabulated. A second table gives the strength data expressed as a % of those of the normally dried lumber.

13. Currier, R. A.

High drying temperatures. Do they harm Douglas-fir veneers? FOREST PRODUCTS JOURNAL v. 8, n. 4, p. 128-136, 1958.

Tests with veneers dried by various direct-fired, and particularly oil-fired heaters at 700°F showed strength reductions of glue bonds compared with steam or kiln-dried veneers but the wood failure in the standard 2-cycle boil DFPA (Douglas Fir Plywood Assoc) tests was quite a reliable index under these conditions. Brushing off sooty deposits found on some of the veneers from oil-fired driers improved the bond but it remained inferior to that of veneer otherwise dried. Tests showed a reduction of water absorbing capacity of veneers with increased temperatures and drying times, and this, it is suggested, may contribute to inferior bonds.

14. Davidson, R. W.

The effect of temperature on the electrical resistance of wood. FOREST PRODUCTS JOURNAL v. 8, n. 4, p. 160-164. May 1958.

Describes tests with Douglas Fir, Yellow Poplar (Liriodendron Tulipfera) and Sugar Maple at 12 to 18% m. c. which largely confirmed earlier findings. At constant m. c. the logarithm of resistance varied linearly with the reciprocal of absolute temperature. Activation energy (i. e., the energy required to release bound ions to enable them to conduct electric current) increased exponentially with decreasing m. c. differences between species were small.

15. Dunlap, F.

THE SPECIFIC HEAT OF WOOD. U. S. Department of Agriculture. Forest Service Bulletin 110. 1912. n.p.

16. Eickner, H. W.

BASIC RESEARCH ON THE PYROLYSIS AND COMBUSTION OF WOOD. U. S. Forest Products Laboratory, Madison, Wisc. Report no. TP-107. Oct 1961. 18p.

The pyrolysis and combustion processes of wood, both untreated and when treated with salts, are being studied by static and dynamic thermogravimetric analysis, differential thermal analysis, heat of combustion of products, and chemical analysis.

The initial results indicate that many of the salts that are good flame retardants lower the threshold decomposition temperature for wood, increase the reaction rate near the threshold temperature, exert an endothermic effect at temperatures at which volatilization is already well underway, and minimize the amount of wood volatilized when pyrolysis is complete. At least one good flame retardant fails to alter the pyrolysis threshold temperature and has an exothermic effect throughout the region of substantial volatilization, but also has the property of minimizing volatilization when pyrolysis is complete.

17. Emvenko, M. P.

The specific heat of wood. DEREVOOBRA-

BATYVAIUSHCHAIA PROMYSHLENNOST'

v. 7, n. 5, p. 18-19, 1958. (In Russian)

In investigations on wood, use was made of G. M. Kondrat'ev's method for determining specific heat, in which the comminuted substance, placed in a small, hollow metal cylinder (microcalorimeter) cools in the air under natural convection conditions and its changes in temperature are measured at regular intervals. A formula is developed for finding the specific heat of the substance in kcal. Results show the specific heat of Scots Pine wood to be 0.38, of Spruce 0.34, of Birch 0.45, and of Birch Bark 0.43 kcal. kg. degree.

18. Fiehl, A. O.

Reducing heat distortion in the knife and

pressure bar assemblies of veneer lathes.

FOREST PRODUCTS JOURNAL v. 8, n. 7,

n.p. July 1958.

19. Fleischer, H. O.

Design of heating equipment for veneer logs.

SOUTHERN LUMBERMAN v. 177, n. 2225, p. 324,

326-328, 330. 15 Dec 1948.

20. Fleischer, H. O.

HEATING RATES FOR LOGS, BOLTS, AND FLITCHES, TO BE CUT INTO VENEER. U.S. Forest Products Laboratory, Madison, Wisc. Report no. 2149. June 1959. 18p.

The heating of logs, bolts, and flitches to be cut into high-quality rotary or sliced veneer requires a knowledge of the temperatures appropriate for various species and conditions, and of the factors that control the attainment of these temperatures during the heating process. Good equipment and good control of the heating process are essential. Under the guidelines given in this paper, optimum temperature levels for different woods and different conditions can be determined, and time schedules can be calculated for heating in steam or water. Optimum temperatures can be determined by following suggested values given for a number of veneer species. Adjustments must be made, depending on the quality of cutting obtained and taking into consideration other species factors, such as tendencies for end-splitting, presence of hard knots, and color changes in the woods. Three steps are involved in arriving at a heating schedule applicable to a given set of conditions. Mathematical analyses have provided graphic shortcuts to aid in taking each step. The first step is to adjust for temperature differences from those assumed in this paper, namely a 70°F. initial wood temperature and a 212°F. heating medium temperature. The second step is to determine the time required to attain the desired temperature under conditions where the heat diffusivity factor is 0.00027. The third step is to adjust the time thus determined to take into account different diffusivity factors that apply to woods of different densities, and that depend on whether the heating is done in steam or in water. Irregularities may occur in the wood or in the heating conditions that may necessitate further adjustment of heating schedules. A number of these are discussed briefly.

21. Fleischer, H. O.

Heating veneer logs. WOOD v. 3, n. 3, Mar 1948. 4p.

Gives heating schedules, based on experiments carried out at Madison, for obtaining optimum conditions for peeling veneer logs of White Oak (Quercus alba), Yellow Birch (Betula lutea), Sweetgum (Liquidambar styraciflua) and Yellow Poplar (Liriodendron tulipfera). The figures given show the temperature to be reached by the heating medium (steam or water), the temperature to be attained by a bolt of 8 in. diameter, and the approximate time required, when heating in water or steam, to reach the optimum temperature for bolts of 12, 24 and 36 inch diameter over bark.

22. Fleischer, H. O. and Lutz, J. F.

Heating veneer logs. WOOD WORKING DIGEST v. 55, n. 12, p. 161-166. Dec 1953.

The method of steaming veneer logs at high temperatures to prepare them for veneer cutting does not result in great saving in heating time, nor in an improvement in veneer quality, commensurate with the cost of installation and operation of the special steaming equipment that is required for the process.

23. Fleischer, H. O. and Downs, L. E.

HEATING VENEER LOGS ELECTRICALLY.

U. S. F' 'est Products Laboratory, Madison, Wisc. Report no. 1958. 1953. 7p.

Presents some typical data (time, voltage, current, and power consumption; also average temperature attained, and temperature range) for Yellow Birch, Red Oak, White Oak, Water Tupelo and Swamp Tupelo.

24. Fleischer, H. O.

THE PERFORMANCE OF WOOD IN FIRE.

U. S. Forest Products Laboratory, Madison, Wisc. Report no. 2202. Nov 1960. 9p.

This report concludes that there was a need for more basic research about the mechanism of combustion of wood and other cellulosic materials, and of methods of imparting resistance against combustion. Many theories exist about how wood may be flameproofed. The theories of greatest interest are those that give promise of leading to effective flameproofing with much smaller amounts of treating material than are now found necessary. This may be accomplished by (1) use of coatings or treatments that release catalysts to interrupt one of the many reactions that form the chain of chemical events known as burning; (2) by impregnating with a material that modifies the burning process so that less of the flammable tars and gases are formed, but more charcoal, water, and other nonflammable gases are produced. Strong acids or bases, or substances that generate strong acids or bases when heated, have the desired chemical action to satisfy the second theory. They act by attaching themselves to the hydroxyl groups of cellulose and upon decomposition

result in the release of the hydrogen and oxygen of cellulose as water, leaving only carbon behind. The ultimate solution to the problem of making wood more acceptable from the fire standpoint lies in the field of basic chemical research along the lines indicated by these theories.

25. Frejdin, A.S.

Effect of radioactive radiation on the physical and mechanical properties of wood. DEREVOOBRABATYVAIUSHCHAIA PROMYSHLENNOST' v.7, n.9, p. 13-15. 1958. (English Trans. by R J. Zatorski. Australian CSIRO TR 4417. 1959. 7p.)

Discusses some Russian, English and American investigations on the subject, and gives details of the strength and swelling pressure of Scots Pine and Ash subjected to various doses of radiation. From statistically treated results, a table is drawn up showing the decrease in wood strength under (a) shear parallel (b) static bending, and (c) compression parallel, for (unspecified) specimens given from 50 to 500 mega-r.e.p. Results given in kg. sq. cm. in the order: control 50 mega. r.r.p., 500 mega, r.e.p were for (a) 74.856.7, 22.5; (b) 825,660, 83-5; (c) 365,385,260.5.

26. Goos, A. W.

The thermal decomposition of wood. In Wise, L. E. and Jahn, E. C. WOOD CHEMISTRY, 2d, ed., N. Y., Reinhold, 1952. Chapter 20.

27. Graf, S. H.

IGNITION TEMPERATURES OF VARIOUS PAPERS, WOODS AND FABRICS. Oregon State College, Corvallis. Engineering Experiment Station. Bulletin no. 26. 1949. 69p.

The bulletin is based on data obtained with semi-automatic apparatus carefully designed to give conditions easily duplicated and comparable to those that could exist in a storage warehouse or a similar building. The substances were tested under conditions of variable specimen weight, variable heating rate, variable air flow, variable atmosphere composition and variable humidity, main effort to obtain the minimum ignition temperatures. The general trend was toward lowered ignition temperature with increase in sample size, with decrease in heating rate, and with increase in oxygen concentration of the atmosphere. There was in most cases an optimum air flow for the lowest ignition temperature, but there was little or no effect on the ignition temperature by low concentrations of water vapor, sulphur, and gasoline fumes.

28. Gt. Brit. Joint Fire Research Organization. Department of Scientific and Industrial Research and Fire Offices' Commission, London.
Prolonged heating of wood. In FIRE RESEARCH BOARD REPORT p. 8-10. 1948.

29. Hawley, L. F. and Wiertelak, J.
Effect of mild heat treatments on the chemical composition of wood.
INDUSTRIAL AND ENGINEERING CHEMISTRY v. 23, p. 184-186. 1931.

The chemical characteristics of samples of white ash and Sitka spruce wood were determined before and after heating in closed tubes at 138° for 2, 4 and 8 days. Losses of pentosans and AcOH occurred in the ash wood whereas in the Sitka spruce the losses were hexosans and stable cellulose. The methoxyl content of both woods was practically unchanged. Indications of a change of carbohydrates to a lignin-like substance were observed.

30. Hearmon, R. R. S. and Burcham, J. N.
Specific heat and heat of wetting of wood.
NATURE v. 176, n. 4490, p. 978. 1955.

Measurement of specific heat and heat of sorption of Beech sawdust give general agreement with the finding of Clarke and Kelsey for Araucaria klinkii, which suggests that the specific heat of wood containing moisture will not depend greatly on species.

31. Giordano, G. and Curro, P.

EFFECT OF TEMPERATURE ON SHEAR STRENGTH OF POPLAR WOOD. International Poplar Commission. 6th Session, Working Party on Exploitation and Utilization, Rome, 1959. FAO/CIP/Ut/9B. 1959. 9p. (In French)

Experiments, designed to elucidate grinding properties, were made on saturated samples (m. c.) nearly 200%) and from two stems of Clone I. 214 Casale Monferrato. Breaking loads in shear fell from 18.04 kg./sq. cm. at 30°C. to 14.16 at 60° and 8.6 at 90%.

32. Horiike, K. and Kato, S.

Heat of wetting of wood. I. Hydrogen bonding and swelling of wood. JAPAN WOOD RESEARCH SOCIETY. JOURNAL v.5, n.5, p. 181-185. May 1959. (In Japanese)

Tabulates the mean values for the heats of wetting for Picea jezoensis with water and 16 chemical solvents. A correlation is suggested between the degree of swelling and heat of wetting, and the swelling behavior of the wood as explained on the hypothesis that its magnitude is directly related to the intensity of the bonding between the constituents of wood and the swelling agent.

33. Kanter, K. R.

The thermal properties of wood.

DEREVOOBRABATYVAIUSHCHAIA

PROMYSHLENNOST' v. 6, n. 7,

p. 17-18. 1957. (In Russian)

Using data from heat measurements of Birch blocks 100 x 100 x 10 m. m., a nomogram was constructed for determining the coefficients of thermal conductivity and diffusivity of Birch. (Similar work has been done in the U.S.S.R.) for Oak. Scots Pine, and Siberian Larch) Conclusions reached from the work are that the specific heat of wood does not depend upon species varying only 3-4%. That thermal conductivity is greater than that; and that thermal conductivity is greater in the radial direction than in the tangential.

34. Kelsey, K. E. and Clarke, L. N.

Effect of temperature and initial moisture content on the heat of wetting of wood. NATURE v. 176, n. 4471.

p. 83-84. 1955.

The authors determined the heats of immersional wetting of wood samples (Araucaria kinkii) having initial moisture contents ranging from 0 to 0.24 g./g., the tests being made at 3 temperatures. The results showed that the effect of temperature on the heat of sorption is adequate to account for the departure of specific heat moisture content relation for cellulosic materials from that of simple mixtures. Since the effect may be regarded as being significant only at m.c's 0. 12 g./g., it is suggested that the energy of the binding of the most strongly held water is relatively unaffected by temperature.

35. Kietaibl, K.

The dry distillation of wood and its thermal balance. In TRANSWORLD CHEMICAL ENGINEERING CONGRESS. WORLD POWER CONFERENCE , London, 1936. PROCEEDINGS v. 3, p. 21-27.

The thermal balance of the dry distillation of wood is given. The conditions for carbonization and for converting wood into gas with the recovery of by-products are discussed.

36. Kitahara, K. and Suematsu, A.

Influence of temperature on the compressive properties of wood. JAPAN WOOD RESEARCH SOCIETY. JOURNAL v. 1, n. 2, p. 47-51. Feb. 1955. (In Japanese)

Air-dry and oven-dry wood of Cryptomeria japonica, chamaeciparis obtusa, Fagus crenata and Red Lauan (Shorea negrosensis?) were subjected to compression $\parallel$ and $\perp$ at different temperatures. For each species and both degrees of dryness, the compressive strength $\parallel$ decreased almost linearly with use in temperature the stress at limit of proportionality and Young's modulus $\perp$ also decreasing. No significant differences in this temperature effect were observed between oven-dry and air-dry wood.

37. Kitahara, K. and Okabe, N.

The influence of temperature on creep of wood by bending test. JAPAN WOOD RESEARCH SOCIETY. JOURNAL v. 5, n. 1, p. 12-18. Jan. 1959. (In Japanese)

Presents graphs showing the time creep relationship in Chamaecyparis obtusa at constant temperatures. Tables indicating, in English, the values obtained at different loads and at different intervals are included.

38. Kollmann, F. and Malmquist, L.

On the heat conductivity of wood and wood-based materials. HOLZ ALS ROH- UND WERKST v. 14, n. 6, p. 201-204. 1956. (In German)

The thermal conductivity (I) of wood parallel to the grain is about twice that across the grain. I across the grain is highest for wood, followed by chipboard and then fiber board. The significance of these relations is discussed.

39. Landt, G. E. and Hausmann, E. O.
Initial inflammability of construction materials. INDUSTRIAL AND ENGINEERING CHEMISTRY v. 27, p. 288-291. 1935.

A method of testing flaming tendency was devised using electric heating. The ignition time was related to the specific heat per unit volume, specific heat conductivity per unit volume and to the existence of microscopic channels.

40. Lawniczak, M. and Raczkowski, J.
Effect of temperature on the strain recovery in wood. NATURE v. 192, p. 583-584. 1961.

Compression experiments at several temperatures on green, maximum swollen beech-wood, indicate that the total strain occurring at the same moment after unloading the wood sample (and regarded commonly as a plastic strain) is only apparently plastic, being the sum of thermo-elastic and real elastic strains.

41. Lawson., D. I. and Simms, D. L.
The ignition of wood by radiation. BRITISH JOURNAL OF APPLIED PHYSICS v. 3, n. 9, p. 288-292, 394-396. Sept 1952.

Minimum intensities of irradiation required to ignite wood, with and without presence of pilot flame, have been determined, and found to be approximately constant for nearly all species; empirical expressions obtained which relate time taken to ignite with intensity of irradiation and density of wood for these two types of ignition.

42. Leont'ev, N. L. et al

Influence of high-temperature drying schedules on the physical and mechanical properties of wood. DEREVOOBRABATY-VAIUSHCHIA PROMYSHLENNOST' v. 5, n. 10, p. 3-5, Oct 1958. (English trans. by M. Slade. Australia. CSIRO TR-3800. 6p)

Scots Pine boards (length 100 cm., width 20-45 cm. thickness 3-6 cm) of intitial m. c. between 62.4 and 108.4% were subjected to high temperature seasoning (maximum temperature 105°-110°c.) using two schedules developed by Soviet Central Research Institute for Mechanical Processing of Wood (CNIIMOD) or else superheated steam (wet-bulb and dry-bulb temperatures 99 and 111° respectively.) Compared with conventional drying, the duration of drying was reduced by a factor 2.1-2.8. Some physical and mehcanical properties of the wood thus dried were determined according to the Soviet Standard GOST 6336-52, treated statistically and compared with those obtained for controls (wood dried by conventional methods). Depending on the schedule used (1st, 2nd and superheated steam), the folloiwng mean deviations (in %) from the controls were obtained: (1) density: -2.0;0.0; (2) compression II: -2.8; -4.5; +4.2; (3) specific work in impact bending: -6.5; 0.0; 0.0; and (4) shear II: -6.8; -6.4-5.0%,

43. Lickess, C. W.

The merits of steaming Douglas-Fir veneer blocks. FOREST PRODUCTS JOURNAL v.7, n.7, n.p. July 1957.

44. Lullin, A.

RECHERCHES SUR LES TEMPERATURES D'INFLAMMATION DU BOIS ET SUR LES ENDUITS IGNIFUGES. Geneva, Imprimerie Albert Kundig, 1925. n.p. (In French)

45. Lutz, J. F.
HEATING VENEER BOLTS TO IMPROVE QUALITY OF DOUGLAS-FIR PLYWOOD. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 2182. Mar 1960. 22p.

The quality of Douglas-fir plywood is directly related to the quality of the veneer. Veneer quality, particularly its smoothness and tightness, can be improved by heating the bolts. This paper describes three methods of heating--hot water, steam, or electricity--and discusses the advantages and limitations of each.

46. MacLean, J. D.
Average temperature and moisture reduction calculations for steamed round southern pine timbers. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 32, p. 256-279. 1936.

47. MacLean, J. D.
Effect of heating in water on the strength properties of wood. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 50, p. 253-281. 1954.

The results obtained in studies of the effect of different water temperatures and different heating periods on the strength properties of small matched specimens of representative softwoods and hardwoods are discussed. Data were obtained on the following strength properties listed in order beginning with the one most affected: (1) work to maximum load, (2) modulus of rupture, (3) fiber stress at proportional limit, and (4) modulus of elasticity.

48. MacLean, J. D.

Effect of oven heating and hot pressing on strength properties of wood. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 51, p. 227-249. 1955.

Results obtained when heating in both the oven and in the hot press showed that, except for the influence of shrinkage or collapse, the bending strength properties were affected in about the following order beginning with the one most affected: (1) work to maximum load (2) modulus of rupture (3) fibre stress at proportional limit (4) modulus of elasticity. This is the same order in which these properties were affected when steam and water were used as the heating mediums. The difference between the respective strength values obtained when heating in the oven or in the hot press was usually not so marked as when heating in steam and in water. The results of oven heating show that the rate of loss in strength was much less when heating in the oven than when heating in steam or water at the same temperature and for the same period. The effects of heating specimens in the hot press were similar to those obtained when they were heated in the oven.

49. MacLean, J. C.

Effect of steaming on the strength of wood. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 49, p. 88-112. 1953.

The data presented show the results obtained in a study of the effect of different steam temperatures and different steaming periods on the strength properties of small matched specimens of representative softwoods and hardwoods. Data were obtained on the following mechanical properties, beginning with the property most affected: (1) work to maximum load, (2) modulus of rupture, (3) fiber stress at proportional limit, (4) modulus of elasticity.

50. MacLean, J. D.

Effect of temperature on the dimensions of green wood. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 47, p. 136-157. 1952.

Experiments show that when green wood is heated it expands tangentially and shrinks radially. This often results in the development of objectionable burst checks or in star checks radiating from the pith, when round timbers, or sawed timbers containing boxed heart, are heated in steam or in hot liquids such as water or preservative oils. A discussion of factors affecting the results is presented. The data show that after the dimensions of green wood have been altered by heating, they do not change as long as the wood remains unseasoned.

51. MacLean, J. D.

METHOD OF COMPUTING THE RATE OF TEMPERATURE CHANGE IN WOOD AND PLYWOOD PANELS WHEN THE TWO OPPOSITE SURFACES ARE MAINTAINED IN DIFFERENT TEMPERATURES. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 1406. Sept 1956. 34p.

It is sometimes useful, as in hot-press gluing, to know the rate of temperature change in wood and plywood panels of any given thickness when the two opposite faces are held at different temperatures. This information is applicable in estimating the approximate time required to obtain a given temperature at a specified distance from the surface, as, for example, in finding the time required to reach the maximum temperature at any point in a panel; in studying the effect of temperatures differences between two hot plates while gluing; in estimating the amount of temperature change that will occur when there is a delay in closing the hot press after loading; and in sterilizing wood vats or churns with hot water or steam. Methods of making such temperature determinations by means of charts which eliminate much tedious calculation are presented as developed by studies at the Forest Products Laboratory.

52. MacLean, J. D.

Rate of disintegration of wood under different heating conditions. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 47, p. 155-168. 1951.

This paper discusses a study of the effect of different heating periods and different temperatures on the physical properties of wood when heated in steam, water, or an oven. The results will be of interest to those using wood where it will be exposed to various temperature conditions, or to those who must heat it prior to use.

53. MacLean, J. D.

RATE OF TEMPERATURE CHANGE IN LAMINATED TIMBERS HEATED IN AIR UNDER CONTROLLED RELATIVE HUMIDITY CONDITIONS. Forest Products Laboratory, Madison, Wisc. Report no. R1434, 1943, n.p.

54. MacLean, J. D.

Rate of temperature change in short-length round timbers. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. TRANSACTIONS v. 68, n. 1, p. 1-16. Jan 1946; (discussion) v. 68, n. 5, p. 567. July 1946.

Factors affecting rate of temperture change in wood suitable for veneer cutting; time temperature curves for determining temperature obtained at different points in short length log sections when heated in steam or hot water; examples are given illustrating procedure for using charts in finding temperature at particular point, under different heating conditions. Bibliography.

55. MacLean, J. D.

THE RATE OF TEMPERATURE CHANGE IN WOOD PANELS HEATED BETWEEN HOT PLATES. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 1299, Nov 1960. 31p.

The purpose of this report is to discuss the rate of temperature change in wood between the heated plates of a hot press, as in the hot-press gluing of plywood, or under similar conditions. The data are of value in determining the time required to obtain a desired temperature, or the temperature that is obtained in a specified time, under various combinations of wood and heating conditions.

56. MacLean, J. D.

Relation of wood density to rate of temperature change in wood in different heating mediums. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 36, p. 220-248. 1940.

This paper discusses results obtained in a study of the relation of factors affecting the rate of temperature change in wood and shows methods for finding the time required to heat timbers of different woods to any desired temperature at various distances from the surface when different heating mediums and temperatures are used.

57. MacLean, J. D.

Studies of heat conduction in wood-- Part II-- Results of steaming green sawed southern pine timbers. AMERICAN WOOD PRESERVERS' ASSOCIATION PROCEEDINGS v. 28, p. 303-329, 1932.

58. MacLean, J. D.

Studies of heat conduction in wood-- results of steaming green round southern pine timbers. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 26, p. 197-217. 1930.

59. MacLean, J. D.

Temperature and moisture changes in coast Douglas fir. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS. v. 31, p. 77-103. 1935.

Rates of temperature change in green and air-seasoned Douglas-fir heated in coal-tar creosote were determined. The amount of H_2O reduction occurring in the heartwood and sapwood when green Douglas fir timbers are heated in creosote under vacuum and rate of temperature change when heated in steam are also discussed.

60. MacLean, J. D.

Temperatures in green southern pine timbers after various steaming periods. AMERICAN WOOD PRESERVERS' ASSOCIATION. PROCEEDINGS v. 30, p. 355-373. 1934.

Method of conducting tests, formulas used in making computations, and tables showing computed temperatures for timbers having various cross-sectional dimensions.

61. MacLean, J. D.

TEMPERATURES OBTAINED IN TIMBERS WHEN THE SURFACE TEMPERATURE IS CHANGED AFTER VARIOUS PERIODS OF HEATING. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 1609. Mar 1956. 60p.

The purpose of this paper is to show when the approximate wood temperature may be determined at any time after the surface temperature is changed and to discuss the various fields in which this information may be used.

62. MacLean, J. D.

Thermal conductivity of wood. HEATING, PIPING AND AIR CONDITIONING. v. 13, n. 6, p. 380-391. June 1941; see also MECHANICAL ENGINEERING v. 63, n. 10, p. 734-735. Oct 1941

Results of large number of heat conductivity experiments that have been made during the last five years at Forest Products Laboratory to determine influence of some of more important variables on thermal conductivity. Before American Society of Heating and Ventilating Engineers.

63. MacLean, J. D.

Thermal conductivity of wood. AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. JOURNAL Sect., HEATING, PIPING AND AIR CONDITIONING v. 47, n. 6, p. 323-354. June 1941

This paper reports and discusses the results of a large number of heat conductivity experiments that were made from 1935-1940 at the Forest Products Laboratory to determine the influence of some of the more important variables on thermal conductivity.

64. MacLean, J. D.

Thermal conductivity of wood. AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS. TRANSACTIONS v. 47, p. 1184-1195. 1941.

65. McNaughton, G. C.

Ignition and charring temperatures of wood. WOOD PRODUCTS v. 50, n. 2, p. 21-22. 1945; also in Forest Products Laboratory, Madison, Wisc. Report no. 1464.

A review. 7 references.

66. McNaughton, G. C. and Harrison, C. A.

Fire resistance tests of plywood covered wall panels. SOUTHERN LUMBERMAN v. 163, no. 2051, p. 31-33. 15 Sept 1941

Study, by Forest Products Laboratory, of fire resistance of plywood wall units when exposed uniformly to fire over one face of structure described; purpose was to learn degree to which resistance to fire was affected by changing details of construction, such as kinds of plywood used, width of studs employed, and type of insulation selected; most of tests made on specimens measuring 2 by 2 ft.

67, Merritt, R. W. and White, A. A.

Partial pyrolysis of wood. INDUSTRIAL AND ENGINEERING CHEMISTRY v. 35, p. 297-301. 1943.

When oak wood is heated in an atmosphere of steam at atmospheric pressure, partial pyrolysis commences below 180°. At 240° the modified wood retains its crushing strength and shows smaller volume changes than the original wood when its moisture content is varied. At that temperature the pentosans have been almost complete decomposed, but 2/3 of the cellulose remains and the lignin shows an apparent increase. Three quarters of the total acid, and half the furfural, but no MeOH, appear in the condensate. The temperature range of 240-260° is critical inspite of control of exothermic reactions. At 260°, the pyrolysed wood has a decided lower crushing strength and commences to show charring. The cellulose has been almost completely destroyed and the lignin cannot be determined because of the presence of charcoal. Only one third of the MeOH has been evolved at 260°. Most of it is evolved above 280°.

The products at 400° show sustantially the same MeOH as in common practice and 25% more acids, the main increase being in formic and propionic acids.

68. Miniutti, V. P.

Fire-resistance tests of solid wood flush doors. FOREST PRODUCTS JOURNAL v. 8, n. 4, p. 141-144. Apr 1958

Describes two series of tests with 1 3/4 in. doors, 3 ft. wide, made of Ponderosa Pine cores, Birch faces, and various cross-band and edge veneers, hung in fire-retardant wood frames or steel frames, showing for all types an effective resistance of ca.1/2 hour.

69. Mitchell, R. L., Seborg, R. M. and Millett, M. A.

Effect of heat on the properties and chemical composition of Douglas-fir wood and its major components. FOREST PRODUCTS RESEARCH SOCIETY. JOURNAL v. 3, n. 4, p. 38-42. Nov 1953.

The effect of heat on the properties and chemical composition of Douglas-fir cross sections and sawdust free from extractives, and the lignin, alpha-cellulose, and hemicellulose isolated from the sawdust was investigated. The materials were heated at different temperatures for different lengths of time in a closed system under pressure and in an open system with and without circulation of air or nitrogen. Variations in the heating conditions not only affected the chemical composition of the volatile products and the residue, but also affected the hygroscopic and dimensional change properties of the residue considerably.

70. Noack, D.

Sorption of wood at elevated temperatures and water vapor pressures.

HOLZ ALS ROH- UND WERKST

v. 17, n. 5, p. 2-5-212. 1959

(In German)

The author describes equipment for measuring the sorption of water vapor at temperatures up to 130° and vapor pressures up to 2.75 kg./sq.cm. The observed values are somewhat higher than the values obtained by extrapolation.

71. Norris, C. B.

How long does it take to bond hot-press plywood. HARDWOOD RECORD v. 76, p. 12-13. June 1938.

72. Northcott, P. L. and Colbeck, H. G. M.

The effect of dryer temperatures on the bending strength of Douglas-fir veneers. FOREST PRODUCTS JOURNAL v. 9, n. 9, p. 292-297. 1959.

High temperatures and drying beyond the oven-dry condition both reduced the static bending strength of heartwood veneers. Though at 375°, the combined effect was neligible, at 450° it was often serious. Differences between trees, and also lathe checks, caused heat variation in values. One conclusion, reached by extrapolating strength changes in veneers of different thickness (0.025-0.14 in.) that surface fibers were more degraded than centre ones, was doubted in discussion on grounds of lack of data for lower temperatures.

73. Ochi, S., Yamazaki, J., and Sumiya, S.

Thermal decomposition of wood and the influence of alkali metal salts of various organic acids on it. KŌGYŌ KAGAKI ZASSHI v. 40, Suppl. binding 213. 1937.

(In Japanese)

Experiments carried out with view to finding cheap and effective fire retardant for wood among salts of organic acids.

74. Ogarkova, T. V.

Temperature deformations of wood during heating. DEREVOOBRABATYVAIUSCHAIA PROMYSHLENNOST' v. 5, n. 5, p. 17-18. May 1956. (In Russian)

Birch-wood test pieces, 12 x 1 x 1 c. m. were weighed and then heated to a constant temperature in a thermostatically controlled oven, the corresponding changes in linear dimension (resulting from thermal expansion and shrinkage due to unavoidable drying being concurrently measured. When the test piece had reached a constant temperature, it was weighted in situ, and maintained there for some time while dimensional changes (due to shrinkage only) were measured. Finally it was again weighted. This procedure enabled the thermal expansion to be determined. For Birch wood of 11.8% initial m. c, the coefficient of thermal expansion was: along the grain 10.0×10^{-6} (total temperature change 77°C), and across the grain 71×10^{-6} (total temperature change 79°). The coefficient of shrinkage was: along the grain 0.0049% (total m. c. change 5.14%); and across the grain 0.246% (total m. c. change 3.55%). Thus shrinkage per 1% m. c. produces the same deformation as a temperature change of 35° (across the grain) and of 5% (along the grain).

75. Ogura, T.

Effect of temperature on the moisture conductivity in wood and on the strain developed in wood as it dries. JAPAN. FOREST EXPERIMENT STATION, TOKYO. v. 77, p. 35-68. 1955. (English trans. U. S. Forest Products Laboratory. TR 415, 13p.)

Using the same material (Quercus borealis), technique and laboratory as J. M. McMullen the effects on drying of temperatures of 95, 110, 125 and 140° F. are detailed. The 5 page English summary and 3 page appendix on formula calculations deal with coefficients for evaporation at constant drying rate, moisture diffusion, moisture conductivity, strain pattern, moisture distribution at maximum strain, magnitude of maximum strain, immediate stress and strain and permanent set, and care in kiln operation.

76. Ogura, T. and Umehara, M.

On the effect of temperature, fiber direction and thickness of board on the diffusion coefficient of wood.

JAPAN WOOD RESEARCH SOCIETY. JOURNAL v. 3, n. 2, p. 51-56. 1957. (In Japanese)

The quantities of moisture moving through test pieces of Chamaecyparis obtusa kept at constant temperatures were measured but no definitive conclusions could be reached on the effect of temperature on the diffusion coefficient λ of wood. The λ of end grain is larger than that of flat and quarter grain. The value of λ increases with board thickness.

77. Ohnuma, K. and Saito, H.

Some aspects of the effect of temperature upon the shrinkage of wood.

JAPAN. FOREST EXPERIMENT STATION, TOKYO. BULLETIN v. 116, p. 75-84. 1959. (English trans. Forest Products Laboratory, Canada. TR 134. 1959. 8p).

In a detailed study, test specimens of Hinoki (Chamaecyparis obtusa) were brought to oven dryness from green and fire saturation point in constant temperatures of 35, 55, 75, and 95°C. The course of moisture loss, total shrinkage rate of shrinkage per unit time and its ratio to total shrinkage at e. m. c. relation between shrinkage and m. c. and between shrinkage at the surface and at various depths (to 30 m. m.) in the specimen are shown in graphs with English captions; also the relation between shrinkage, m. c. stress, and hot pressing (105° C. and 0.3-4.2 kg./sq. cm).

78. Perkitny, T., Lawniczak, M. and Marciniak, H.

The influence of steaming on the swelling pressure of wood. HOLZ ALS ROH- UND WERKST v. 17, n. 2, p. 54-61. 1959. (English trans. by J. Hardy. Australia. CSIRO TR 4804. 16p.)

Samples of Beech sapwood 30 x 30 x 20 m. m., carefully prepared from pieces that had been steamed for 0, 1, 2, or 3 hours, were used in investigations on water absorption, free swelling and swelling pressure. Results are tabulated and graphed. Although the final maximum values for free swelling were not lowered, but were rather slightly increased by steaming, a marked and lasting reduction in the maximum swelling pressure of the steamed samples was recorded.

79. Perry, T. D. and Bretl, M. F.

Hot pressing technique for plywood. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. TRANSACTIONS v. 60, n. 1, p. 69-76, Jan 1938.

History of cold pressing with various adhesives; development and adoption of hot pressing with thermosetting synthetic resin adhesives which are more water resistant than adhesives developed for cold pressing; various types of domestic and foreign hot presses; effect of heat on tensile strength of wood, characteristics of resin film.

80. Prince, R. E.

Tests on the inflammability of untreated wood and wood treated with fire retarding compounds. In NATIONAL FIRE PROTECTION ASSOCIATION. PROCEEDINGS. 1915. n.p.

81. Runkel, R. O. H. and Wilke, K. D.

Thermoplastic properties of wood. HOLZ ALS ROH- UND WERKSTOFF v. 9, p. 260-270. 1951. (In German)

Wood (beech and spruce) was heated under different conditions of time, temperature, pressure, and moisture content. With temperature as variable (200 atm., 4 min., 15% H_2O, up to 190°), total carbohydrate drops rapidly (especially beech); alpha-cellulose shows little change; lignin increases very slightly; total solubles, (H_2) and EtOH) increase rapidly, especially at 170° where total carbohydrate decreases H_2O absorption and swelling (28 days) decrease rapidly; bending strength increases to a maximum at 180°; and toughness increases very slowly to a maximum at 180° With H_2O content as variable (200 at., 4 min., 185°, up to 30% H_2O), at up to 5% H_2O there is very little decrease in total carbohydrate and very little increase in total solubles. With increasing H_2O content total carbohydrate drips to a constant value at 20% H_2O and total solubles increase to a constant value. Strength rises to a maximum at 10% H_2O and then drops rapidly. Two general types of reactions are discussed to explain the data: (1) hydrolysis of hemicellulose, and (2) condensation (e.g. furfural) to resinous material. The latter accounts for thermal plasticity of wood and for the reduced swelling and water uptake.

82. Seborg, R.M., Tarkow, H. and Stamm, A.J.

Effect of heat upon the dimensional stabilization of wood. FOREST PRODUCTS RESEARCH SOCIETY. JOURNAL v.3, n. 3, p. 59-67. Sept 1953.

Thermal treatment of wood in the presence or absence of oxygen leads to a reduction in swelling capacity (in water). Simultaneously there occur severe losses in toughness and abrasion resistance.

83. Stamm, A. J. and Hansen, L. A.

Minimizing wood shrinkage and swelling--effect of heating in various gases. INDUSTRIAL AND ENGINEERING CHEMISTRY v. 29, p. 831-833. 1937.

Specimens of white pine 9 x 2 x 0.6 cm. were heated in a bomb in atmospheres of H_2, air, 0_2 and illuminating gas to several temperatures for short intervals of time, then soaked in water for five days. The pine heated in H_2 at 165° for as short a time as 15 minutes with and without soaking in water for five days, then brought to equilibrium at 26.7° under 90 and 30% humidities for two weeks, gave an anti-shrink efficiency (wt.), 6.3% (without soaking) and 1.8% (with soaking) respectively. When heated for two hours under these same conditions the efficiencies were 17.0 and 11.4%, respectively. Illuminating gas gave somewhat higher values than for H_2. Air gave values slightly under those for illuminating gas while 0_2 gave considerably higher values.

84. Stamm, A. J., Burr, H. K. and Kline, A. A.

Staybwood. . . Heat-stabilized wood. INDUSTRIAL AND ENGINEERING CHEMISTRY v. 38, p. 630-640. 1946.

Extensive data are presented on the reduction in hygroscopicity of wood when heated beneath the surface of a molten metal over the temperature range 120° to 320° and time range of 1 minute to 1 week. The degree of reduction in hygroscopicity and equilibrium swelling and shrinkage for a given time of heating is practically doubled for each 10° rise in temperature. Reductions in hygroscopicity are shown to be accompanied by appreciable increases in decay resistance and significant losses in strength. Serious losses in strength for many possible uses are not obtained until the reductions in hygroscopicity and antishrink efficiency exceed 50%.

85. Stamm, A. J.

Thermal degradation of wood and cellulose. INDUSTRIAL AND ENGINEERING CHEMISTRY v. 48, n. 3, p. 413-417. Mar 1956.

Weight loss of wood when heated either in an oven or beneath the surface of a molten metal follows first-order reaction rates. Activation energies have been calculated for the degradation booth from weight loss and from strength loss data; these are similar. Extrapolation of data indicates little degradation of wood in one hundred years' storage at room temperature under dry conditions.

86. Stamm, A. J. and Loughborough, W. K.

Thermodynamics of the swelling of wood. JOURNAL OF PHYSICAL CHEMISTRY v. 39, p. 121-132. 1935.

Determinations were made (for the system Sitka sprucewood-water) of the relative vapor pressure-moisture content desorption isotherms. Temperatures varied from room temperature to 100°, and conditions were carefully controlled to minimize the hysteresis effect. Fiber-saturation points decrease linearly with increasing temperatures and are reduced by 0.1% per 1° rise. Smooth curves were formed (with zero values at the fiber saturation point) for the differential heats of swelling, and free energy and entropy which were calculated over the entire sorption range. The relationship between mechanism of sorption and the nature of these curves is discussed. Comparative data on the heats of swelling and free energy and entropy changes for the swelling and solution in H_2O of various (biological) organic substances and for H_2SO_4 are included.

87. Stamm, A. J. and Loughborough, W. K.

Variation in shrinking and swelling of wood. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. TRANSACTIONS v. 4, n. 5, p. 379-386. 1942.

While forces that cause wood to shrink and swell are chemical in nature, factors which influence degree of external dimensions change are largely physical or mechanical; orientation of structural units, specific gravity or porosity of wood, and stresses set up by moisture gradients determine change in external dimensions as wood loses or gains moisture.

88. Stevens, W. C.

The thermal expansion of wood. WOOD

(London) v. 25, n. 8, p. 328-329.

Aug 1960.

Describes and illustrates the apparatus used in experiments to determine the coefficient of thermal expansion of moistureless specimens of Beech and Scots Pine. The experiments showed that thermal movements of wood are of small significance being ca. 1/18 and 1/15 that of the corresponding moisture movements in Beech and Pine respectively.

89. Tamaru, S., Imai, Y. and Momma, S.

Physicochemical studies of wood. JAPAN.

CHEMICAL SOCIETY. JOURNAL v. 55,

p. 30-52. 1934. (In Japanese)

About 30 anti-igniting chemicals, $(NH_4)_2HPO_4$, H_3PO_4, $(NH_4)_2SO_4$, etc., were tried. These chemicals decreased the gaseous formation from the thermal decomposition of wood, especially below red heat. The prevention of gaseous formation by the chemical treatment was greater in wood than in pure cellulose at 500°, but this effect was reversed when they were heated at 700°. Therefore, the lignin, and not cellulose, in wood is attacked at 500. Different chemicals, did not give the same effect, but, with the same chemical, the more the wood was impregnated, the less was the gaseous formation by heat. The rate of decomposition of wood by heat treatment is estimated. There is a discontinuity in gaseous and charcoal formation from wood at 310-320° if heated at high temperature for many hours. Quick heating of wood in a white hot furnace caused the loss of C as volatile gas and decreased the rate of carbonization. The charcoal showed less density and hardness, while slow heating gave a product of high density and hardness. Wood impregnated with $ZnCl_2$, H_2SO_4, H_3PO_4, etc., gave less contraction on heating and gave charcoals of high density and hardness. Carbonization of wood without any oxidation process caused the formation of inactive C; active C was not formed by heating the wood below 550° even when it was impregnated with H_2SO_4 or H_3PO_4; impregnation with $ZnCl_2$ produced activation at low temperature.

90. Treesdale, L. V.

THERMAL INSULATION MADE OF WOOD-BASE MATERIALS. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 1740, Rev., Oct 58, 76p.

Basic information on the thermal insulation of wood and wood-base materials, including their influence on fuel economy, comfort of occupants, attic ventilation, vapor barriers, fire hazard, and cold weather condensation is presented. Also, included are procedures necessary for calculating the thickness of insulation required for a specified installation. The aims of this report are: (1) to assist in a careful estimation of where, when, and why insulation is needed; (2) to show how the different wood-base materials meet specific requirements; (3) to emphasize some of the principles frequently overlooked that should be followed in the proper installation of insulation.

91. Trapp, W. and Pungs, L.

Effect of temperature and moisture content on the dielectric properties of untreated wood over a large frequency range. HOLZFORSCHUNG, v. 10, no. 5, p. 144-150, 1956. (In German)

Dielectric values of sprucewood were measured and loss factors were determined under conditions in which the frequencies and the moisture varied at constant temperature or in which the frequency and the temperature varied, and the percentage of moisture remained constant. From an extensive series of tridimensional models and from graphs, it was shown that dielectric behavior is of 3 types, corresponding to 3 types of sorption. The authors attempt to explain their data in terms of the theories of Debye, Wagner, Dänzer and others.

92. Truax, T. R.

FIRE RESEARCH AND RESULTS AT THE FOREST PRODUCTS LABORATORY. U. S. Forest Products Laboratory, Madison, Wisc. Report no. 1999, Oct 59, 14p.

Investigations of the ignition temperature of wood, while informative, have not yielded results that can be used for predicting the actual performance of wood under

fire conditions, nor in evaluating the significance of fire-retardant treatments and coatings. Fire spread is the characteristic of wood that is most affected by fire-retardant treatments and coatings. Size, form, density, moisture content, and arrangement of members are other factors that have an important affect on the fire-spread characteristic of wood. Resistance of wood to destruction by fire, such as rate of penetration of fire and maintenance of structural properties under standard time-temperature conditions, is affected by its physical properties and structural details. Resistance to charring is not greatly increased by fire-retardant treatments, perhaps at most by some 10 to 20 percent. Good performance of wood construction under fire conditions is obtained by taking advantage of the self-insulating qualities of wood, by employing good structural details, and by using fire-retardant treatments and coatings where circumstances warrant. There is much yet to be learned about wood and wood products in relation to fire.

93. Underwriters' Laboratories, Inc., Chicago, Ill.

IGNITION OF WOOD AT LOW TEMPERATURES.

Card C60. Card Data Service, n. d.

94. U.S. Forest Products Laboratory, Madison, Wisc.

COMPUTED THERMAL CONDUCTIVITY OF COMMON WOODS. Technical note no. 248. Rev.,

Dec 1952, 6p.

Determinations of the thermal conductivity of wood at various moisture contents were made. The tests, which covered 32 species, furnished sufficient data on relationship between conductivity, specific gravity, and moisture content to make it possible to compute the approximate thermal conductivity for any wood for which specific gravity is known and for which the moisture content can be determined or assumed. Such conductivities have many practical applications, such as in estimating the thermal resistance or insulating value of various woods, thermal resistance being the reciprocal or inverse value of conductivity.

95. U.S. Forest Products Laboratory, Madison, Wisc.

FUEL VALUE OF WOOD. Technical note no. 98.,

Rev., June 1956, 2p.

Two pounds of dry wood of any non-resinous species have about as much heating value as a pound of good coal. Speaking in tons and cords, a tone of coal may be taken as equivalent value of one cord of heavy wood, 1-1/2 cords of medium-weight wood, or 2 cords of light wood.

96. U.S. Forest Products Laboratory, Madison, Wisc.

IGNITION AND CHARRING TEMPERATURES OF WOOD. Report no. 1464, Jan 1958. 6p.

The purpose of this report is to indicate the importance of time in the effects of heat upon wood rather than to present specific values for ignition temperatures or to recommend methods for determining such temperatures.

97. Vorreiter, L.

The swelling of timber as a function of a number of variable factors, particularly temperature and timber dimension. HOLZ ALS ROH- UND WERKST v.13, no. 8, p. 302-312, 1955. (English trans. by H. E. Kijlstra. Australia. CSIRO TR 3059, 21p.

The author determined the swelling of spruce specimens (15 mm. in logitudinal direction and 10-45 sq. mm. in cross section) in H_2O at different temperatures. During the first hour, at all temperatures (20-90°), tangential swelling (I) is concave to the time axis; radial swelling (II) is convex. With increasing temperature, the rate of swelling increases, as well as maximum swelling (III) in both directions. At all temperatures, the III in both directions decreases with increasing size in a measured direction. Thus, at 20° tangential III is 7% for a specimen of 10 mm. and 3.8% of 45-mm. dimension. At a given temperature the ratio (IV) of I to II decreases with increasing dimensions; however, beyond 63 mm. IV increases with temperature. Thus for a specimen 40 x 40 mm., IV is 1.61 at 20° and 1.75 at 80°. The author gives relations between I and II as a function of density (constant specimen size). Previous work has shown that tropical hardwoods do not give reliable relations, since their swelling is markedly influenced by inclusions of resinous materials. The valid relations are of limited use owing to the effect of specimen size. The author quotes from a dissertation of B. Marschalleck to the effect that with red beech (30 X 30 mm.) with increasing temperature (20 - 130°) at a constant moisture content (for example, 20%, I increases from 6.8 to 8.8%, II from 4.4 to 4.8%.

98. Wangaard, F. F.

The effect of wood structures upon heat conductivity. AMERICAN SOCIETY OF MECHANICAL ENGINEERS. TRANSACTIONS. 1942, 8p.

Shrinkage and swelling, mechanical properties, and working qualities of wood are all related to orientation of structural units of cell wall; effect of fibrillar orientation upon heat-conducting properties of wood indicates new technique for selection of various qualities of wood; application of longitudinal transverse conductivity ratios is proposed particularly for detection of mild compression of wood.

99. Weatherwax, R. C. and Stamm, A. J.

THE COEFFICIENTS OF THERMAL EXPANSION OF WOOD AND WOOD PRODUCTS. U.S. Forest Products Laboratory, Madison, Wisc. Report no. 1487, Mar 56, 46p.

Data are reported on the thermal expansion of natural solid wood, plywood, impreg, compreg, papreg, staypak, hydrolyzed wood, plastics and laminated sheets. The coefficients of linear thermal expansion were measured on each of these materials in three structural directions. The variation of these coefficients with specific gravity was determined on a series of 26 solid, oven dry specimens of 9 different species of untreated wood. The effects of radial compression, resin treating, and cross-banding on the values of the coefficients were determined on a series of 23 birch laminates. The values of the coefficients for papreg and hydrolyzed-wood plastic were also determined. General formulas were developed that permit calculation of the coefficients linear thermal expansion of wood in any grain direction of the specimen from the original and final specific gravities, the percentage by weight of resin and glue present, the percentage of cross-banding, and the slope of grain relative to any three axes of reference.

100. Wright, R.H. and Hayward, A.M.

Kinetics of the thermal decomposition of wood. CANADIAN JOURNAL OF TECHNOLOGY. v 29, p. 503-510, 1951.

The effects of particle size and of temperature on the rate of decomposition of western red cedar and western hemlock were studied in connection with the production of fuel gas from waste wood. Wood specimens were cut into cubes having edges from 3 mm. to 19 mm. and weighing from 1.5 to 3.3 g. and dried for 24 hours at 105°. Depending on their size, 1-140 cubes were dropped into a 60-1. reaction vessel filled with N and heated to 500°, 700°, or 900°. By measuring pressure changes within the reactor, the reaction for cubic pieces were found to be of the 1/2 order. The rate constant is directly proportional to the specific surface and to the temperature, and the proportional to the specific surface and to the temperature, and the proportionality constants

are the same for both species of wood. The following equation which applies to both species, was derived: $k = (1/LD-0.75)(0.00065T-0.4)$, density in g./cc.; T=temperature in °K. The time required for 99% decomposition of a sample is 18/k. When disks 2 cm. in diameter and 0.3 cm. thick are used, the reaction was of the zero order, and those disks cut across the grain decomposed approximately twice as fast as those cut along the grain.

101. Youngs, R. L.

Recent progress toward an understanding of the physical and mechanical properties of wood.

FOREST PRODUCTS JOURNAL p. 214-225, May 1961.

This review briefly surveys some of the developments and progress made during the past five years in striving toward a better understanding of the physical and mechanical properties of wood, their significance, and their interrelationship. Much of the work holds considerable promise for the future.

AUTHOR INDEX